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Predictors of postoperative complications in the patient with diabetes mellitus

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Abstract

Background: Since patients with diabetes mellitus have increased rates of cardiovascular morbidity and mortality, it is critical to evaluate cardiovascular risk perioperatively. Although several preoperative risk indices have been developed, including the Goldman and Detsky indices, none have been designed specifically for diabetic patients. In this study, we attempted to identify predictors of postoperative cardiac and noncardiac complications in diabetic patients undergoing elective general surgery. **Study Design:** A cohort of 107 diabetic patients undergoing elective surgery was assembled. Basic demographic and clinical data were recorded perioperatively, and all patients were followed up prospectively daily for 7 days postoperatively. Patients were interviewed at 5 years postoperatively. Univariate and multivariate analyses were performed to identify predictors of postoperative complications and long-term cardiac and vascular morbidity and mortality. **Results:** Total cardiac complications and myocardial infarction were predicted by the Goldman index. Wound complications were not predicted by any of the variables studied. At 5 years postoperatively, cardiac and vascular deaths and events were predicted by age, history of myocardial infarction or stroke, presence of vascular disease, Goldman index, duration of diabetes or hypertension, Charlson comorbidity score, and postoperative myocardial infarction or cardiac arrest. Blood sugar control during surgery was not predictive of any short- or long-term cardiovascular complications. **Conclusions:** Total cardiac complications had a significant preoperative predictor: the Goldman index. Both preoperative and postoperative variables and indices predicted long-term cardiac and vascular complications. Further study is necessary to investigate these relationships to better assess and manage the diabetic patient in the perioperative setting.

Keywords: Cardiac complications; Diabetes mellitus; Outcomes

1. Introduction

Patients with diabetes mellitus are more likely to have accelerated atherosclerosis and more extensive coronary artery disease (Kannel & McGee, 1979; Robertson & Strong, 1968). It may, therefore, be particularly important to evaluate cardiovascular risk in this population during the perioperative setting. In fact, Thourani et al. (1999) reported that diabetes is a significant independent predictor of both short-term (perioperative) and long-term (10 years) mortality in patients undergoing coronary artery bypass grafting; furthermore, in the same study, insulin requirement in diabetic patients during surgery was a significant multivariate correlate of long-term all-cause mortality. Other studies have shown that diabetes is an important predictor of postoperative cardiac events (Hollenberg, Mangano, & Browner, 1992; Mangano, Browner, & Hollenberg, 1990; Mangano, Browner, & Hollenberg, 1992; McFalls, Ward, & Santilli, 1998; Wong & Detsky, 1992), including infarction, ischemia and death, cerebrovascular events (Attum et al., 1998; Hogue, Murphy, Schechtman, & Davila-Roman, 1999), and renal failure (Conlon et al., 1999).

In order to more precisely risk stratify patients undergoing surgery, several different prognostic indices have been developed, several of which consider diabetes to be an independent risk factor. The original cardiac risk index that was described by Goldman, Caldera, and Nussbaum (1977)

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assessed risk based on information obtained from the patient's history, physical examination, and preoperative laboratory testing. This model has since been refined, and others have also been proposed, including the Detsky risk index (Detsky, Abrams, & McLaughlin, 1986) and the Eagle criteria (Eagle & Boucher, 1989). However, none of these risk indices are designed specifically for diabetic patients.

The objective of this study was to identify predictors of perioperative complications and long-term outcomes among diabetics undergoing surgery.

2. Research design and methods

2.1. Patients

All patients who had diabetes mellitus and underwent general surgery at the New York Hospital from July 1982 to September 1985 were eligible for enrollment. Criteria for having diabetes mellitus included the following: (a) treatment with insulin or oral hypoglycemic agents before admission, including treatment that was started during preoperative evaluation; (b) elevated fasting blood glucose ≥140 mg/dl on more than one occasion before operation. Patients undergoing any elective general surgery were eligible for enrollment, including intra-abdominal procedures, peripheral vascular or aneurysm surgery, or other operations such as amputation or hemorrhoidectomy. A prospective cohort of 107 diabetic patients was thus assembled prospectively (Charlson et al., 1990).

2.2. Data collection

Clinical characteristics of the population were established according to explicit criteria: (a) demographic information; (b) past diabetic history including retinopathy, neuropathy, and nephropathy; (c) presence of comorbid disease, including hypertension, ischemic heart disease, congestive heart failure, valvular heart disease, stroke or transient ischemic attacks, peripheral vascular disease, acute infection, and known metastatic carcinoma; (d) presence of diabetic complications; (e) medications; (f) preoperative laboratory and roentgenologic data; (g) type and duration of anesthesia and operation; (h) methods of perioperative glucose control; (i) perioperative serum glucose values; and (j) development of postoperative complications. Criteria for the diagnosis of comorbid disease and postoperative complications have been detailed previously (Charlson et al., 1991). Cardiac complications included the occurrence of cardiac arrest, myocardial infarction, ischemia, or congestive heart failure. Wound complications included the need for reoperation, development of infection, or wound dehiscence.

Each patient was followed up for 7 days postoperatively or until death, discharge, or reoperation. Daily recordings of the occurrence of any change in clinical condition, the development of medical or surgical complication, and blood glucose level (up to four times per day) were made prospectively. Patients were also followed up at 5 years postoperatively to determine if any complications or deaths had occurred.

Various cutoff points to define a hyperglycemic episode were evaluated; definitions included those established by Bjerke and Shabot (1992), Hirsch (1995), and Queale, Seidler, and Brancati (1997). Perioperative glucose control was then assessed by calculating the rate of hyperglycemic episodes within the 7-day postoperative period (total number of hyperglycemic episodes/total number of assessments; Queale et al., 1997; see Table 3).

2.3. Analysis

Univariate analysis and multivariate analyses were performed using the LOGIST (logistic regression using PROCLOGIST) procedure in Statistical Analysis System (SAS) for dichotomous variables (The LOGISTIC Procedure, n.d.). The Cox proportional hazards model was then used to evaluate the association between time to death or event and the occurrence of perioperative complications or other covariates; this analysis was employed to control for confounders and conducted using the PHREG (proportional hazard regression using PROCPHREG) procedure in SAS for life tables (The LOGISTIC Procedure, n.d.).

3. Results

The mean age of the patients was 62 years (range=19–93 years), and men constituted 47% of the population. Diagnosis of diabetes had been made from 5 to 10 years in 32% and more than 10 years in 46%. Oral medication for diabetes was being used by 33% of patients, while 49% used insulin and 20% used diet alone. Preoperatively, diabetic end-organ damage was as follows: 22% had retinopathy, 15% had nephropathy, and 37% had somatic neuropathy. Only 2% had visceral neuropathy. Hypertension was also present in 63% of patients, and 11% had suffered a previous myocardial infarction. Baseline characteristics are summarized in Table 1.

Immediate postoperative complications for each patient were noted and included the following: 27% had cardiac complications, such as cardiac arrest, myocardial infarction, myocardial ischemia, and congestive heart failure (Table 1). An additional 9% had wound complications.

3.1. Predictors of perioperative complications

When the univariate analysis was performed to evaluate the predictive qualities of preoperative clinical risk factors (shown in Table 1), only the Goldman index predicted both overall cardiac complications (P=.022) and myocardial infarction (P=.025). Blood glucose control did not add to the model in which the Goldman index was found to be

Table 1
Preoperative characteristics and immediate postoperative complications (N=107)

	Value
Preoperative patient characteristics	
Age in years (mean±S.D.)	61.7±14.0
Sex	
Male	46.7
Female	53.5
Race	
Caucasian	57.0
African American	29.9
Hispanic	12.1
Asian	0.9
Goldman class	
1	62.6
2	24.3
3	12.1
4	0.9
Duration (in years) with diabetes mellitus	
<5	21.9
5–10	32.3
>10	45.8
Diabetic complications	
Retinopathy	21.5
Nephropathy	15.0
Neuropathy	
Somatic	37.4
Visceral	1.8
Hypertension	62.6
Duration (in years) with hypertension	
<5	59.8
5–10	19.6
>10	20.6
Smoking	51.4
CVA	12.1
MI	11.2
Angina	14.9
PVD	41.1
Immediate postoperative complications	
Cardiac complications (total)	27.1
Cardiac arrest	4.7
Myocardial infarction	7.5
Myocardial ischemia	7.5
Congestive heart failure	7.5
Wound complications (total)	9.3
Reoperation	4.7
Infection	2.8
Dehiscence	2.8
Fever	20.6

Values (except for age) are expressed as percentages.

significant; however, given the lack of power in this study, it is possible that a significant relationship existed but was not detected. No other variables were predictive.

To assess the ability of blood glucose control to predict complications, we constructed a summary variable that would provide a composite assessment of each patient's glycemic control over time: blood glucose control was calculated by totaling the number of hyperglycemic events (for each of several different definitions' or methods' cutoff points) over the 7-day postoperative period and then dividing it by the total number of measurements for a given patient. Table 2 depicts the relationships between the rates of blood glucose control and postoperative cardiac or infectious complications. None of the cutoff points for serum glucose predicted cardiac or wound complications.

Table 2
Percentage of time[a] that the patient was hypoglycemic in relation to complications

	Cutoff point of blood sugar		
	200	300	400
Cardiac complications (total)	0.92	0.19	0.30
Wound complications (total)	0.81	0.67	0.66
Infection	0.08	0.11	0.41
Dehiscence	0.95	0.77	0.76
Fever	0.23	0.03	0.56

[a] Total number of hyperglycemic measures defined by cutoff point/total number of measurements.

3.2. Long-term follow-up

At 5 years, 35% had cardiac deaths or events: 25% had died from a cardiac event, 10% suffered a myocardial infarction, and 11% had congestive heart failure (Table 3). Over the same period of time, 21% had vascular deaths or events: 4% died from a CVA or renal failure, 12% had a CVA, and 6% suffered renal failure.

Table 4 shows the unadjusted odds ratios for different demographic, perioperative, and postoperative variables for the development of long-term cardiac and vascular complications. In predicting the development of cardiac deaths and events, age, history of myocardial infarction, presence of vascular disease, Goldman index, duration of both diabetes and hypertension, comorbidity score, and postoperative cardiac arrest or myocardial infarction were all significant in univariate analysis. The perioperative glucose control, at any of the three different thresholds of blood glucose, was not significant.

In predicting the development of vascular deaths and events, similar variables were found to be statistically significant. Age, history of CVA or myocardial infarction, presence of vascular disease, Goldman index, duration of diabetes or hypertension, total comorbidity score, and

Table 3
Proportion of patients who developed specific cardiac or cardiovascular events at 5 years' follow-up

	n (%)
Cardiac deaths and events	37 (34.6)
All cardiac deaths	27 (25.2)
All myocardial infarctions	11 (10.3)
All congestive heart failure	12 (11.2)
Vascular deaths and events	22 (20.6)
Death from CVA or renal failure	4 (3.7)
CVA	13 (12.2)
Renal failure	6 (5.6)
Total cardiovascular deaths and events	53 (49.5)
Cardiovascular death	31 (29.0)
Cardiovascular event	36 (33.6)

Table 4
Unadjusted odds ratios according to the demographic and preoperative characteristics, postoperative complications, and perioperative blood glucose control rates for the development of cardiac and vascular deaths and events at 5 years' follow-up

	Risk ratio (*P* value)	
	All cardiac deaths/events	All vascular deaths/events
Age	1.056 (.0008)	1.048 (.0003)
Sex	0.684	0.891
Stroke	0.944	4.396 (.0003)
Myocardial infarction	2.833 (.0001)	2.256 (.0003)
Vascular disease	3.469 (.0028)	2.636 (.0047)
Goldman index	2.473 (.0001)	2.131 (.0003)
Duration of diabetes	1.021 (.0388)	1.022 (.0287)
Duration of hypertension	1.051 (.0031)	1.033 (.0365)
Total comorbidity score	1.754 (.0001)	1.625 (.0001)
Postoperative complications		
Cardiac arrest	5.414 (.0272)	3.167
Myocardial infarction	3.633 (.0379)	2.195 (.0300)
Ischemia	0.476	0.651
Congestive heart failure	1.388	0.912
Total cardiac complications	1.981	1.485
Reoperation	0.000	0.800
Wound dehiscence	0.000	0.000
Fever	1.225	0.896
Perioperative glucose control		
Rate (threshold=200)	0.293	0.303
Rate (threshold=300)	0.182	0.390
Rate (threshold=400)	0.001	0.019

postoperative myocardial infarction were all predictive of vascular deaths or events at 5 years' follow-up. Again, perioperative glucose control was not found to be predictive of any long-term vascular complications.

To select the optimal set of variables that predicts long-term morbidity and mortality, we performed a stepwise proportional hazards regression analysis (Table 5). Age, total comorbidity score, and total postoperative cardiac complications all predicted deaths. Duration of hypertension and total comorbidity score predicted cardiac deaths and events. Finally, history of stroke, Goldman index, and total comorbidity score predicted vascular deaths and events. It is notable to recognize that the total comorbidity score was the only variable that was predictive of events of every type (deaths or events, cardiac or vascular).

4. Conclusions

In this study, we have shown that the postoperative outcome of total cardiac complications (including cardiac arrest, myocardial infarction, myocardial ischemia, and congestive heart failure) has a significant predictor, namely, the Goldman index. Contrary to previous studies (MacKenzie & Charlson, 1988), existing comorbidities such as congestive heart failure and valvular disease were not found to be predictive of postoperative complications. Although these factors are elements of the Goldman index, it was only the combination of them that proved to be significant. In this context, it is important to stress the utility of the Goldman index, as it may assist the individual physician in risk stratification, and the need for additional preoperative testing or evaluation.

It may be interesting to further compare the Goldman index with other cardiac risk indices to determine which index has the highest degree of sensitivity and specificity for determining outcomes in the diabetic population. A study by Gilbert, Larocque, and Patrick (2000) compared four different methods for predicting perioperative risk: the Goldman index, the modified Detsky index, the American Society for Anesthesiologists index, and the Canadian Cardiovascular Society index. Each of the four models performed slightly better than chance in predicting specific cardiac complications but did not differ significantly from one another. Hence, a consensus regarding which risk factors or indices are most useful in predicting perioperative cardiovascular morbidity and mortality in the diabetic patient has yet to be reached.

Diabetic patients have also been demonstrated to have higher rates of postoperative infection when compared to nondiabetic patients (Boyko & Lipsky, 1995). This may be due to the direct effects of hyperglycemia on immunoglobulin and leukocyte function or the indirect effects of long-term microvascular complications. It is important to note that no predictors of postoperative infection were identified in this study, including blood glucose control at any of several different diagnostic thresholds. This is contrary to several previously published reports documenting higher rates of wound infection after cardiac surgery in diabetic patients with uncontrolled hyperglycemia. Studies by Golden, Peart-Vigilance, Kao, and Brancati (1999) and Zerr et al. (1997) found that postoperative hyperglycemia, particularly in the first 36 h, led to increased rates of infection. Furthermore, tight glucose control with the use of a continuous intravenous infusion of insulin significantly reduced the incidence of infectious complications in patients undergoing cardiac surgery (Furnary, Zerr, Grunkemeier, &

Table 5
Adjusted odds ratios for cardiac deaths/events and vascular deaths/events

	Risk ratio (*P* value)	
	All cardiac deaths/events	All vascular deaths/events
Age		
Stroke	6.940 (.0001)	
Myocardial infarction		
Vascular disease		
Goldman index	2.063 (.0052)	
Duration of diabetes		
Duration of hypertension	1.085 (.0002)	
Total comorbidity score	6.101 (.0002)	1.651 (.0001)
Postoperative complications		
Cardiac arrest		
Myocardial infarction		

Starr, 1999). A potentially significant difference that exists between our population of patients and those investigated previously is the fact that all of our patients underwent general, not cardiac, surgery. It is possible that cardiac surgery represents greater stress or selects more severe diabetic patients with microvascular disease such that infectious complications are more common.

When considering predictors of long-term complications, both preoperative and postoperative variables were significant. The medical history of the patient must, therefore, be evaluated very carefully, specifically to assess comorbid conditions that place the patient at higher risk for either cardiac or vascular disease (The Diabetes Control and Complications Trial Research Group, 1993; UK Prospective Diabetes Study Group, 1998). This risk is reflected in such variables as the total comorbidity score, the Goldman index, or the duration of hypertension or diabetes. Postoperative complications of cardiac arrest and myocardial infarction predicted both cardiac and vascular deaths and events with odds ratios between 2.2 and 5.4. It should be noted that glucose control did not predict any long-term complications.

It should be emphasized, however, that the results of this study reflect a very specific population of patients and should not be generalized to patients without diabetes mellitus or those undergoing cardiac surgery. The size of our cohort was also relatively small, and the limited number of complications, particularly wound complications, may have lessened the potential for finding significant relationships between our variables and outcomes. Without adequate power, it is difficult to conclusively assert that there is no relationship between perioperative glucose control and either short- or long-term complications. In order to draw stronger conclusions regarding preoperative predictors of postoperative complications, further prospective studies consisting of larger populations of diabetic patients are warranted.

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